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(54) **PROCESS OF FABRICATING THERMAL BARRIER COATINGS**

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C23C 4/12 (2006.01)
C23C 24/04 (2006.01)

(52) **U.S. Cl.**
CPC .. ***C23C 4/12*** (2013.01); ***C23C 24/04*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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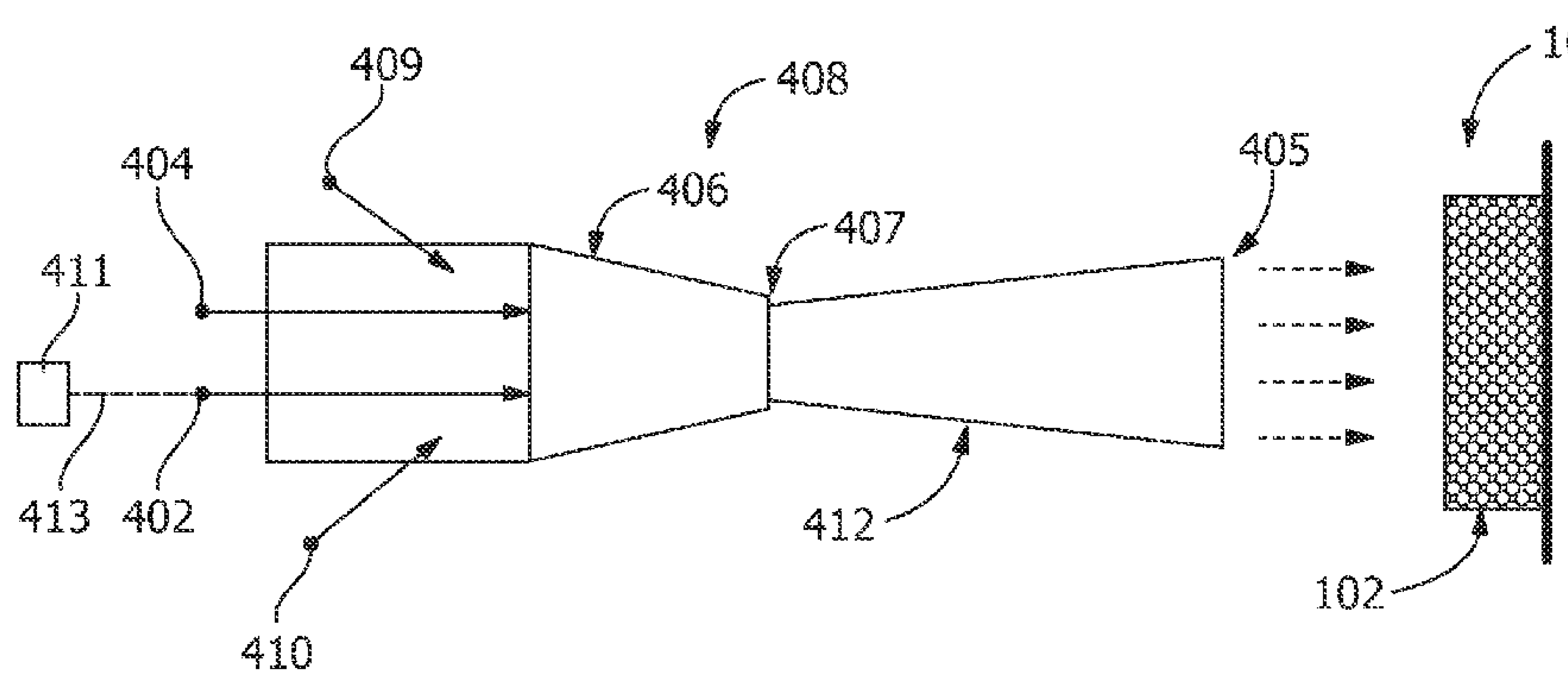
(57) **ABSTRACT**

A process of fabricating a thermal barrier coating is disclosed. The process includes cold spraying a substrate with a feedstock to form a thermal barrier coating and concurrently oxidizing one or more of the substrate, the feedstock, and the thermal barrier coating. The cold spraying is in a region having an oxygen concentration of at least 10%. In another embodiment, the process includes heating a feedstock with a laser and cold spraying a substrate with the feedstock to form a thermal barrier coating. At least a portion of the feedstock is retained in the thermal barrier coating. In another embodiment, the process of fabricating a thermal barrier coating includes heating a substrate with a laser and cold spraying the substrate with a feedstock to form a thermal barrier coating.

20 Claims, 4 Drawing Sheets



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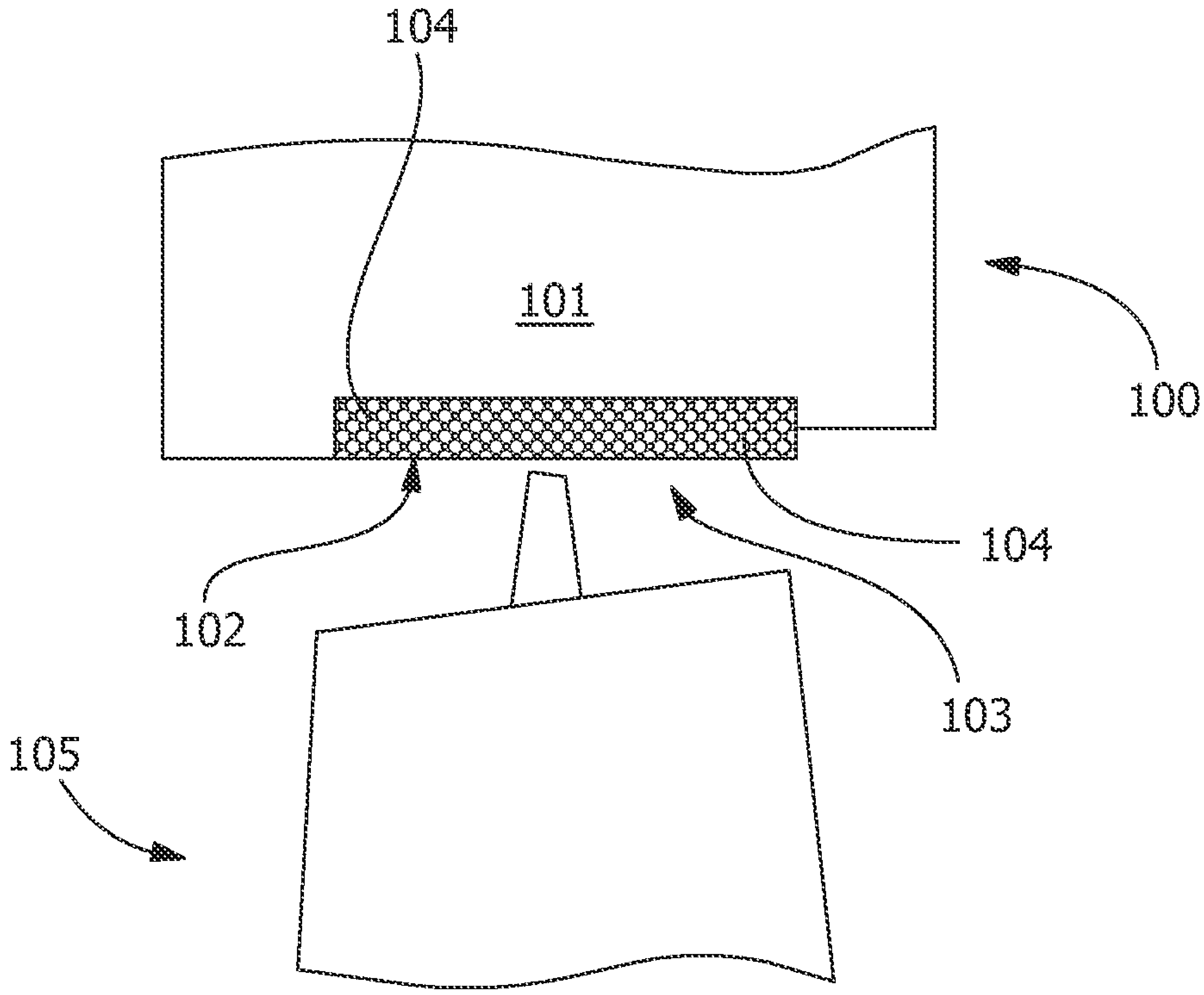

FIG. 1

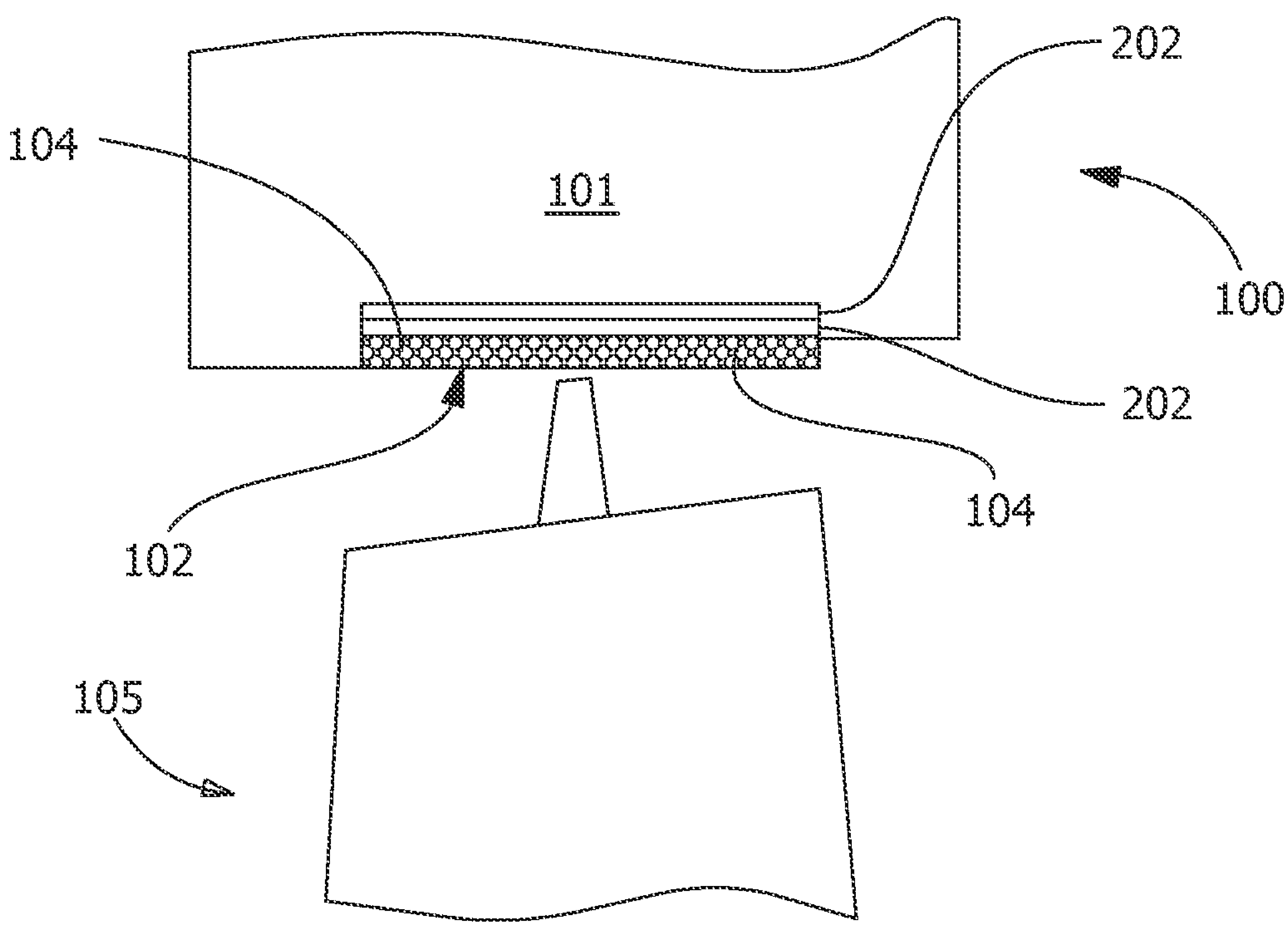

FIG. 2

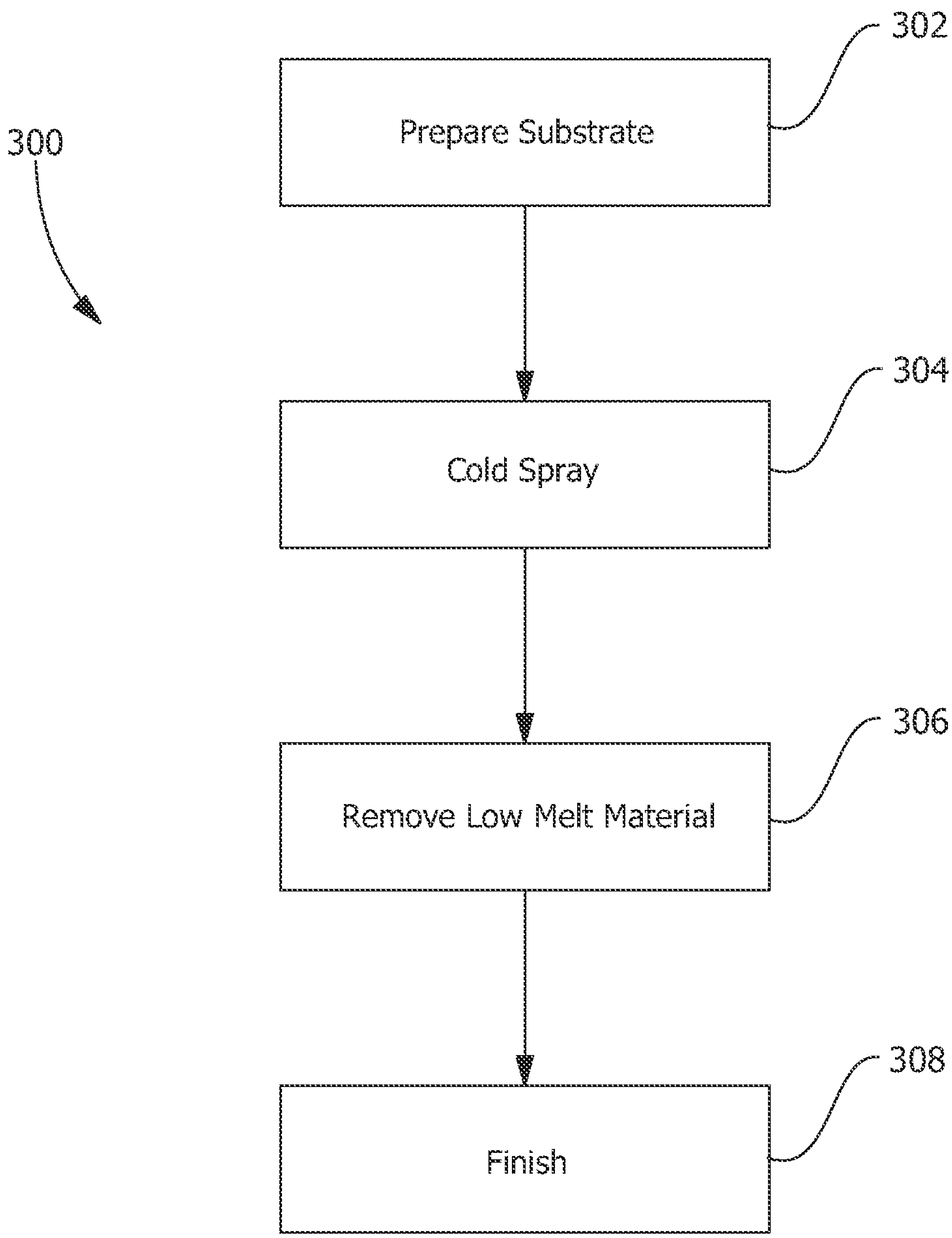
302
300
Prepare Substrate
304
Cold Spray
306
Remove Low Melt Material
308
Finish

FIG. 3

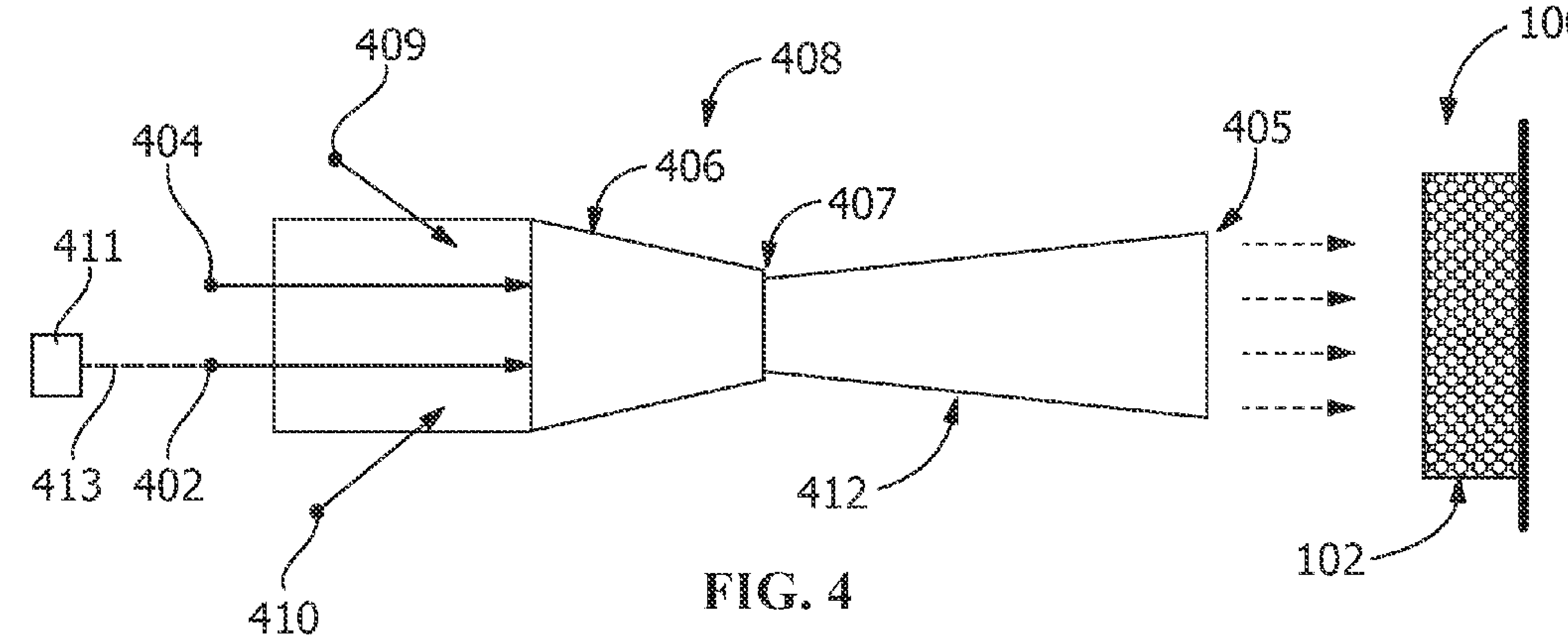
409
408
100
404
406
405
411
407
413
402
412
102
410

FIG. 4

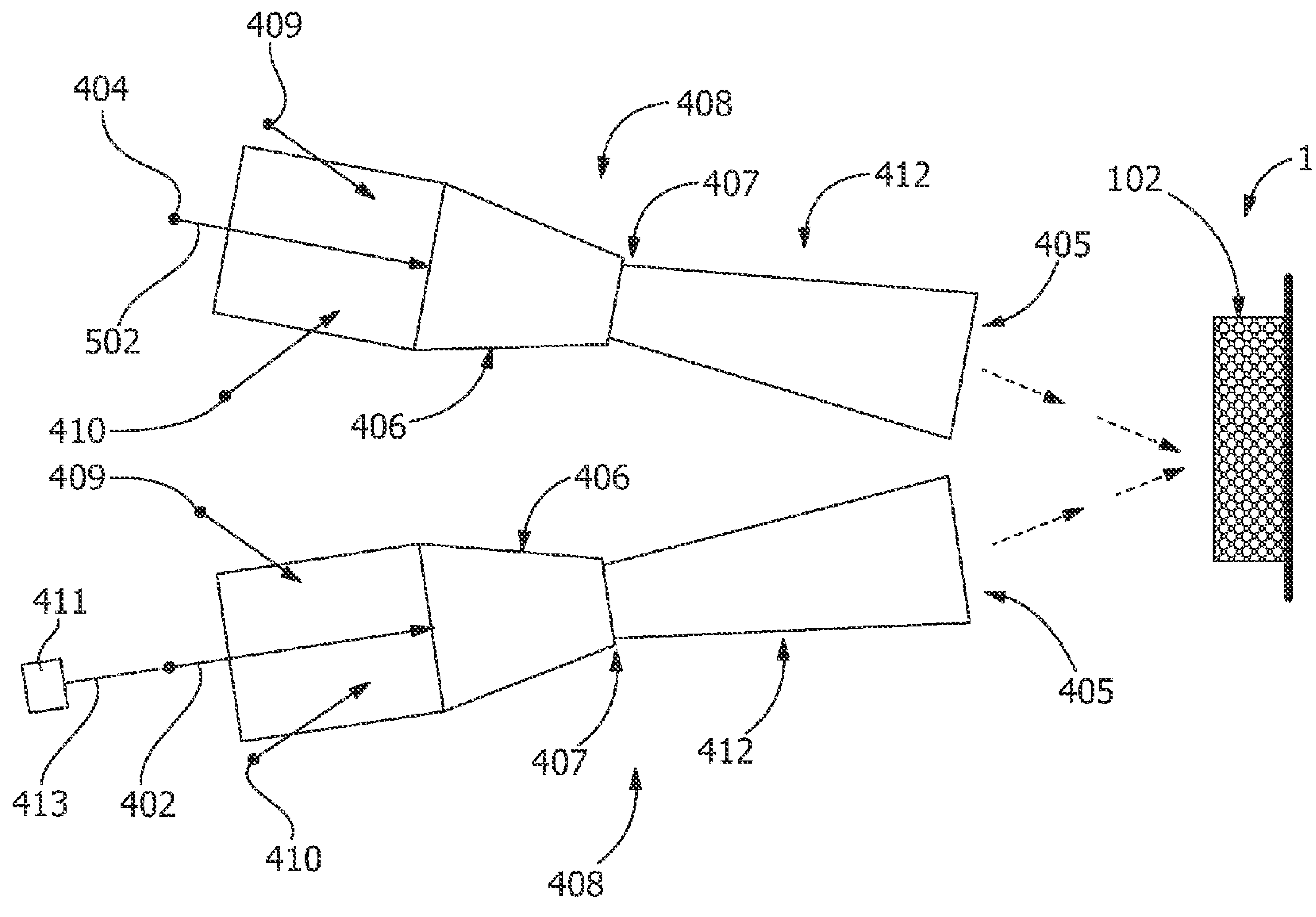
409
404
408
100
407
412
102
405
502
410
406
409
406
411
405
413
402
407
412
410
408

FIG. 5

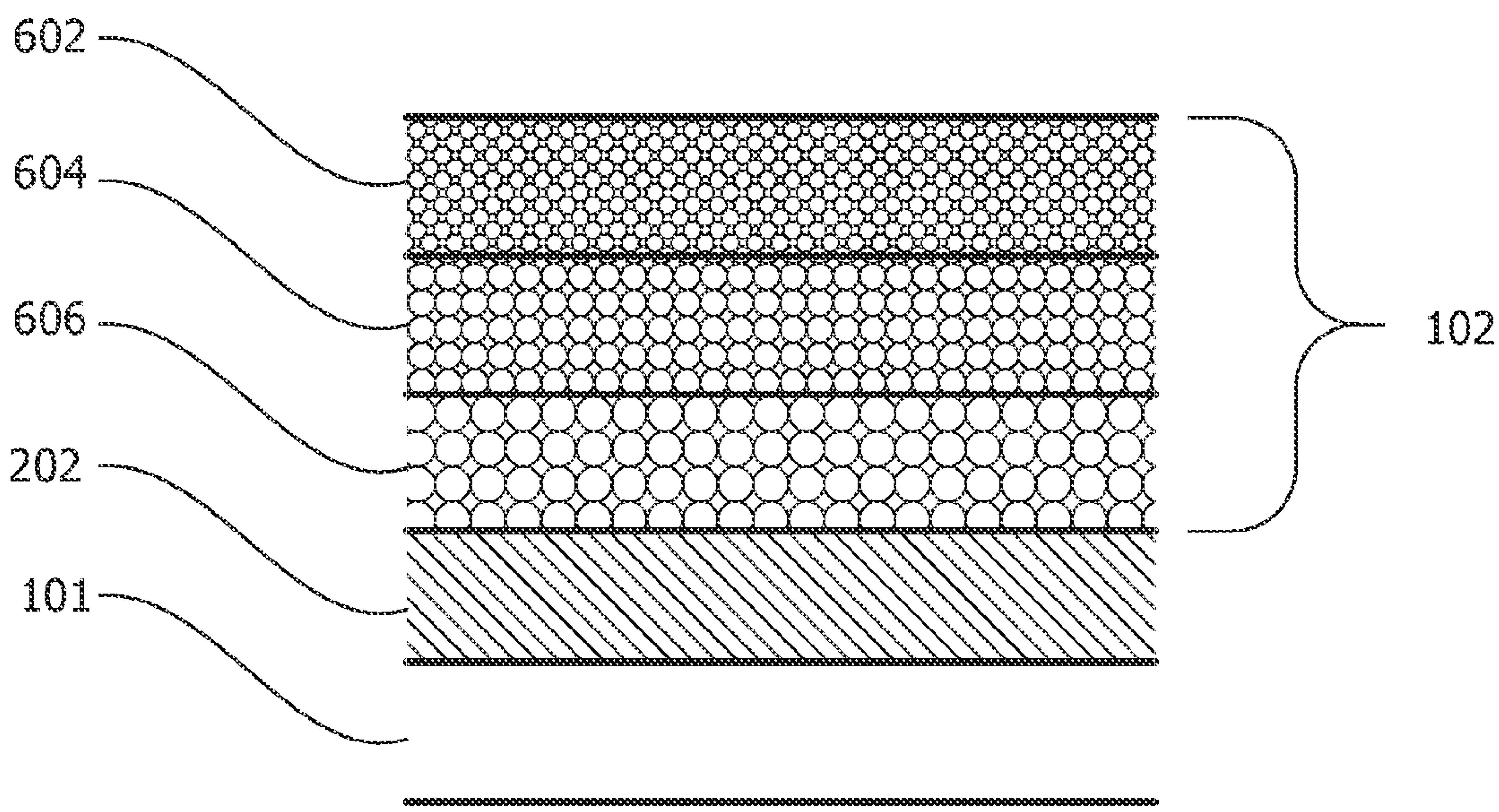

FIG. 6

PROCESS OF FABRICATING THERMAL BARRIER COATINGS

RELATED APPLICATION

This application is a continuation-in-part of and claims priority to U.S. patent application Ser. No. 13/354,412, filed Jan. 20, 2012, titled "Process of Fabricating a Thermal Barrier Coating and an Article Having a Cold Sprayed Thermal Barrier Coating," which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

The present invention is directed to a process of fabricating thermal barrier coatings and turbine components having thermal barrier coatings. More specifically, the present invention is directed to cold spray to form thermal barrier coatings.

BACKGROUND OF THE INVENTION

Many systems, such as those in gas turbines, are subjected to thermally, mechanically and chemically hostile environments. For example, in the compressor portion of a gas turbine, atmospheric air is compressed to 10-25 times atmospheric pressure, and adiabatically heated to a temperature of from about 800° F. to about 1250° F. in the process. This heated and compressed air is directed into a combustor, where it is mixed with fuel. The fuel is ignited, and the combustion process heats the gases to very high temperatures, in excess of about 3000° F. These hot gases pass through the turbine, where airfoils fixed to rotating turbine disks extract energy to drive the fan and compressor of the turbine, and the exhaust system, where the gases provide sufficient energy to rotate a generator rotor to produce electricity. Tight seals and precisely directed flow of the hot gases provide operational efficiency. To achieve such tight seals in turbine seals and providing precisely directed flow can be difficult to manufacture and expensive.

To improve the efficiency of operation of turbines, combustion temperatures have been raised and are continuing to be raised. To withstand these increased temperatures, thermal barrier coatings (TBC) are often used as sealing structures for hot gas path components. An ability of the TBC to protect the hot gas path components from the rising temperatures is limited by a thermal conductivity of the TBC. The lower the thermal conductivity of the TBC, the higher the temperature the TBC can withstand.

An increased porosity in the TBC may decrease the thermal conductivity of the TBC. However, current methods of TBC deposition, including electron beam physical vapor deposition (EBPVD) and air plasma spraying (APS), are unable to form the desired porosity while maintaining a required mechanical strength in the TBC. Additionally, current TBC chemistries that have low K value constituents, like lanthana for example, cannot be deposited by APS to the thicknesses required for effective TBC layer due to the formation of a glass phase that disrupts the spraying process.

A fabrication process and an article that do not suffer from one or more of the above drawbacks would be desirable in the art.

BRIEF DESCRIPTION OF THE INVENTION

In an exemplary embodiment, a process of fabricating a thermal barrier coating includes cold spraying a substrate with a feedstock to form a thermal barrier coating and concurrently oxidizing one or more of the substrate, the feedstock, and the thermal barrier coating. The cold spraying is in a region having an oxygen concentration of at least 10%.

In another exemplary embodiment, a process of fabricating a thermal barrier coating includes heating a feedstock with a laser and cold spraying a substrate with the feedstock to form a thermal barrier coating. At least a portion of the feedstock is retained in the thermal barrier coating.

In another embodiment, a process of fabricating a thermal barrier coating includes heating a substrate with a laser and cold spraying the substrate with a feedstock to form a thermal barrier coating.

Other features and advantages of the present invention will be apparent from the following more detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a seal arrangement having one layer positioned between a shroud and a blade according to an embodiment of the disclosure.

FIG. **2** shows a seal arrangement having multiple layers positioned between a shroud and a blade according to an embodiment of the disclosure.

FIG. **3** shows a flow diagram of an embodiment of a process of applying a metallic structure according to the disclosure.

FIG. **4** shows a schematic view of an apparatus for forming an article having a metallic structure applied according to an embodiment of the process of the disclosure.

FIG. **5** shows a schematic view of an apparatus for forming an article having a metallic structure applied according to an embodiment of a process of the disclosure.

FIG. **6** shows an article with multiple layers of a thermal barrier coating according to an embodiment of the disclosure.

Wherever possible, the same reference numbers will be used throughout the drawings to represent the same parts.

DETAILED DESCRIPTION OF THE INVENTION

Provided is a process of fabricating a thermal barrier coating. Embodiments of the present disclosure, for example in comparison to processes not employing one or more of the features disclosed herein, provide increased ceramic retention in deposits, increased oxide content of the deposits, graded porosity layers, mica fillers, increased porosity, decreased thermal conductivity value, controlled thermal barrier coating microstructure, and combinations thereof.

FIGS. **1** and **2** show articles **100**, such as a turbine shroud positioned adjacent to a turbine blade **105**, having a thermal barrier coating **102**. In one embodiment, the thermal barrier coating **102** forms a turbine component, such as a turbine seal. The thermal barrier coating **102** is positioned directly on a substrate **101** of the article **100**, as shown in FIG. **1**, or is positioned on one or more intermediate layers **202** on the substrate **101**, as shown in FIG. **2**. In one embodiment, the thermal barrier coating **102** forms a low thermal conductivity portion in comparison to other portions of the article **100**.

The article **100** is any suitable metallic component, such as a stationary component or a rotating part. Suitable metallic components include, but are not limited to, compressor components, turbine components, turbine blades, and turbine buckets. As used herein, the term "metallic" is intended to encompass metals, alloys, composite metals, intermetallic materials, or any combination thereof. In one embodiment, the article **100** includes or is stainless steel. In another embodiment, the article **100** includes or is a nickel-based alloy. Other suitable alloys include, but are not limited to, cobalt-based alloys, chromium based alloys, carbon steel, and combinations thereof. Suitable metals include, but are not limited to, titanium, aluminum, and combinations thereof.

The thermal barrier coating **102** is positioned on any suitable portion or surface of the article **100**. In one embodiment, the thermal barrier coating **102** is a portion of the article **100**, such as, a hot gas path of a turbine, a fillet, the turbine seal, a compressor seal, a labyrinth seal, a brush seal, a flexible seal, a damping mechanism, a cooling mechanism, bucket interiors, pistons, heat exchangers, or combinations thereof.

The thermal barrier coating **102** is formed by cold spraying of a solid/powder feedstock **402** (see FIGS. **4** and **5**) in a region **103** having an oxygen concentration of at least 10%. In one embodiment, the oxygen concentration is above about 50%. In one embodiment, the oxygen concentration is above about 70%. The feedstock **402** includes, but is not limited to, ceramic particles and a binder **404** (FIG. **4**). In one embodiment, the thermal barrier coating **102** includes a network of pores **104**. In one embodiment, the pores **104** are have limited visual discernibility and/or have a fine porosity. In another embodiment, the pores **104** are complex and do not have a consistent geometry, similar to steel wool, and/or have a coarse porosity. The pores **104** are any suitable size and within any suitable density. Suitable sizes of the pores **104** are between about 1 and about 100 microns, between about 10 and about 50 microns, between about 30 and about 40 microns, between about 50 and about 100 microns, between about 50 and about 70 microns, or a combination thereof. Suitable densities of the pores **104** are between about 5% and about 85%, about 15% and about 75%, about 15% and about 25%, about 25% and about 75%, about 2% and about 15%, and combinations and sub-combinations thereof.

Referring to FIG. **2**, in one embodiment, the thermal barrier coating **102** is positioned on two of the intermediate layers **202**, one of which is positioned on the substrate **101** of the article **100**. In further embodiments, the metallic structure is positioned on three, four, five, or more of the intermediate layers **202**.

Referring to FIG. **3**, in an exemplary process **300** of applying the thermal barrier coating **102**, the article **100** is prepared (step **302**), for example, by cleaning the surface of the article **100**. The thermal barrier coating **102** is then applied to the article **100** by cold spray (step **304**). The cold spraying (step **304**) includes spraying the feedstock **402** (see FIGS. **4** and **5**) and the processing takes place mostly in a solid condition with less heat than processes such as welding or brazing. In one embodiment, the cold spraying (step **304**) applies the thermal barrier coating **102** to a predetermined region. In one embodiment, the predetermined region of the thermal barrier coating **102** is capable of being at a tighter tolerance than otherwise possible without use of masking. In one embodiment, the thermal barrier coating **102** is applied without using masking and is capable of being reproduced. In one embodiment of the article **100**, the thermal barrier coating **102** is or includes a reproducible feature that is capable of being replicated without masking. In one embodiment, the thermal barrier coating **102** has a tensile adhesion strength greater than a predetermined amount, for example, greater than 1000 PSI, greater than 3000 PSI, greater than 5000 PSI, or greater than 10,000 PSI.

In one embodiment, the solid feedstock **402** includes ceramic particles, such as yttrium stabilized zirconium, ytterbium zirconium, pyrochlores, other suitable ceramic particles, or combinations thereof. For example, in one embodiment, the ceramic particles include rare earth stabilized zirconia, stabilized by a rare earth metal selected from the group consisting of Y, Yb, Gd, Nd, La, Sc, Sm, and combinations thereof. In another embodiment, the ceramic particles include non-rare earth stabilized zirconia, stabilized by a material selected from the group consisting of Ca, MG, Ce, Al, and combinations thereof. In one embodiment, the solid feedstock **402** includes ceramic particles clad in a binder or adhesive. In one embodiment, the ceramic particles in the solid feedstock **402** have a predetermined maximum dimension, for example, less than about 20 micrometers, less than about 10 micrometers, between about 5 micrometers and about 20 micrometers, between about 5 micrometers and about 10 micrometers, at about 10 micrometers, at about 5 micrometers, or any suitable combination or sub-combination thereof. In one embodiment, the solid feedstock **402** includes sintering aids, such as Al_2O_3, SiO_2, other suitable sintering aids, or combinations thereof.

In one embodiment, the solid feedstock **402** includes mica. Mica is a silicate (phyllosilicate) mineral that includes several closely related materials having close to perfect basal cleavage. Micas have the general formula $X_2Y_{4-6}Z_8O_{20}(OH,F)_4$. Common micas include, but are not limited to, biotite, lepidolite, muscovite, phlogopite, zinnwaldite, and combinations thereof. Mica decomposes between temperatures of about 850° C. to about 1200° C. In one embodiment, mica is used as a filler material below its decomposition temperature. In one embodiment, mica is heated above its decomposition temperature, forming the pores **104** in the thermal barrier coating **102**.

In one embodiment, the solid feedstock **402** is prepared by a method including, but not limited to, mixing, milling, spray drying, coating, contacting the feedstock with a plasma flame, or a combination thereof. In another embodiment, the solid feedstock **402** is prepared by coating the ceramic particles with a metallic material, for example, using an electroless method to coat the ceramic particles with nickel. In another embodiment, the solid feedstock **402** is prepared by passing the solid feedstock **402** material through a plasma flame and collecting the sprayed material.

Referring to FIG. **4**, in one embodiment, the solid feedstock **402** is mixed with the binder **404** within or prior to a converging portion **406** of a converging-diverging nozzle **408**. In one embodiment, the solid feedstock **402** is a substantially homogenous mixture of the ceramic particles, and the binder **404**. The binder **404** has a melting point lower than the ceramic particles. Additionally or alternatively, the binder **404** has a ductility greater than the ceramic particles (at conditions of cold spray). In one embodiment, the solid feedstock **402** is pre-mixed with the binder **404** providing further adjustability, for example, at any suitable volume concentration. Suitable volume concentrations for the binder **404** are between about 5% and about 90%, between about 5% and about 10%, between about 5% and about 15%, between about 5% and about 20%, between about 5% and about 30%, between about 5% and about 50%, between about 5% and about 60%, between about 5% and about 70%, between about 5% and about 80%, between about 10% and about 90%, between about 20% and about 90%, between about 30% and about 90%, between about 40% and about 90%, between about 50% and about 90%, between about 60% and about 90%, between about 70% and about 90%, between about 80% and about 90%, between about 30% and about 60%, between about 40% and about 50%, between about 10% and about 15%, or any suitable combination or sub-combination thereof.

The binder **404** is a polymer, a mixture of polymers, a non-polymeric material, a metallic material, any material suitable for use in cold spray applications and/or with thermal barrier coatings, or combinations thereof. In one embodiment, the binder **404** is or includes polyester. In other embodiments, the binder **404** is or includes titanium, aluminum, nickel, cobalt, iron, alloys thereof, polyamide (nylon), nylon with glass fiber reinforcement, poly butylene terepthalate (PBT), polypropylene (PP), polyethylene (PE), polyphenylene sulfide (PPS), a blend of polyphenylene oxide and polystyrene, or combinations thereof. For example, in one embodiment, a combination of polymers is based upon melting points.

Referring to FIG. **6**, in one embodiment, the thermal barrier coating **102** includes several layers each having the binder **404**, for example, an exterior thermal barrier layer **602**, an intermediate thermal barrier layer **604**, and an interior thermal barrier layer **606**. In this embodiment, the volume concentration of the binder **404** is adjusted, thereby adjusting the porosity of the thermal barrier coating **102** as a whole. For example, in one embodiment, the external thermal barrier layer **602** includes binder of a first density (for example, about 25%), the intermediate thermal barrier layer **604** includes binder of a second density (for example, a greater amount than the first density and/or between about 25% and about 40%), and the interior thermal barrier layer **606** includes binder of a third density (for example, a greater amount than the second density and/or between about 40 and about 75%). In one embodiment, the thermal barrier coating **102** and/or one or more of the layers of the thermal barrier coating is/are substantially devoid of metal or metallic materials.

In one embodiment, the thermal barrier coating **102** includes, but is not limited to, low thermal conductivity chemistries such as 68.9 wt % Yb_2O_3, balance ZrO_2, high Y 55 wt % ZrO_2, or combinations thereof. In one embodiment, the thermal barrier coating **102** includes, but is not limited to, ultra low thermal conductivity chemistries such as 30.5 wt % Yb_2O_3, 24.8 wt % La_2O_3, balance ZrO_2, and combinations thereof.

The cold spraying (step **304**) forms the thermal barrier coating **102** by impacting the solid feedstock **402** particles. The cold spraying (step **304**) substantially retains the phases and microstructure of the solid feedstock **402**. In one embodiment, the cold spraying (step **304**) is continued until the thermal barrier coating **102** is within a desired thickness range or slightly above the desired thickness range (to permit finishing), for example, between about 1 mil and about 2000 mils, between about 1 mil and about 100 mils, between about 10 mils and about 20 mils, between about 20 mils and about 30 mils, between about 30 mils and about 40 mils, between about 40 mils and about 50 mils, between about 20 mils and about 40 mils, or any suitable combination or sub-combination thereof.

Referring to FIG. **4** and FIG. **5**, in one embodiment, the solid feedstock **402** is pre-heated with a laser beam **413** from a laser **411** prior to cold spraying (step **304**). The pre-heating of the solid feedstock **402** increases retention of the solid feedstock **402** in the thermal barrier coating **102** deposits. In another embodiment (not shown), the laser **411** is utilized to heat the substrate **101** prior to cold spraying (step **304**). In another embodiment, the laser **411** is utilized to heat the substrate **101** after the cold spraying (step **304**). Heating the substrate **101** with the laser **411** increases a temperature surrounding the substrate **101**, also leading to increased retention of the feedstock **402** in the thermal barrier coating **102**. The heating of the substrate **101** with the laser **411** also increases an oxygen concentration surrounding the substrate.

An increased retention of the feedstock **402** forms an increased porosity in the thermal barrier coating **102**. In one embodiment, the increased porosity in the thermal barrier coating **102** decreases the thermal conductivity of the thermal barrier coating **102**. For example, in one embodiment, the porosity of the thermal barrier coating **102** is between about 20% and about 40%, between about 20% and about 30%, between about 25% and about 35%, between about 30% and about 35%, between about 30% and about 40%, or any suitable combination or sub-combination thereof.

In one embodiment, the cold spraying (step **304**) includes accelerating the solid feedstock **402** through the converging-diverging nozzle **408**. The solid feedstock **402** is accelerated to at least a predetermined velocity or velocity range, for example, based upon the below equation for the converging-diverging nozzle **408** as is shown in FIG. **4**:

$$\frac{A}{A^*} = \frac{1}{M}\left[\frac{2}{\gamma+1}\right]\left[1+\left(\frac{\gamma-1}{2}\right)M^2\right]^{\frac{\gamma+1}{2(\gamma-1)}} \quad \text{(Equation 1)}$$

In Equation 1, "A" is the area of nozzle exit **405** and "A*" is the area of nozzle throat **407**. "γ" is the ratio C_p/C_v of the process gas **409** being used (C_p being the specific heat capacity at constant pressure and C_v being the specific heat capacity at constant volume). The gas flow parameters depend upon the ratio of A/A*. When the nozzle **408** operates in a choked condition, the exit gas velocity Mach number (M) is identifiable by the equation 1. Gas having higher value for "γ" results in a higher Mach number. The parameters are measured/monitored by sensors **410** positioned prior to the converging portion **406**. The solid feedstock **402** impacts the article **100** at the predetermined velocity or velocity range and the solid feedstock **402** bonds to the article **100** to form the thermal barrier coating **102**.

In one embodiment, the solid feedstock **402** is cold sprayed (step **304**) through the converging-diverging nozzle **408** using a process gas **409**. The process gas **409** includes, but is not limited to, helium, nitrogen, oxygen, air, or combinations thereof. In one embodiment the process gas **409** provides an increase in oxygen concentration in the region **103** where the thermal barrier coating **102** is formed. In another embodiment, an inlet gas provides an increase in oxygen concentration in the region **103** where the thermal barrier coating **102** is formed.

The increase in oxygen concentration increases an oxidation of the metallic components in the thermal barrier coating **102**. An oxide concentration in the thermal barrier coating **102** is increased by the increase in the oxidation of the metallic components.

The nozzle **408** is positioned a predetermined distance from the article **100**, for example, between about 10 mm and about 150 mm, between about 10 mm and about 50 mm, between about 50 mm and about 100 mm, between about 10 mm and about 30 mm, between about 30 mm and about 70 mm, between about 70 mm and about 100 mm, or any suitable combination or sub-combination thereof.

In one embodiment, the cold spraying (step **304**) includes impacting the solid feedstock **402** in conjunction with a second feedstock, for example, including the binder **404**. Referring to FIG. **4**, the binder **404** is injected with the solid feedstock **402**, injected separate from the solid feedstock **402** but into the same nozzle **408**, injected into a separate nozzle **408**, or injected into a diverging portion **412** of the same nozzle **408** or the separate nozzle **408**. In an embodiment with the binder **404** injected into the diverging portion **412**, the effect of heat, such as degradation of the binder **404**, from a processing gas is reduced or eliminated. In one embodiment, the binder **404** includes a material susceptible to damage, such as degradation from the heat of the processing gas, up to about 1500° C. The injection in the diverging portion **412** reduces or eliminates such degradation. Another embodiment uses a single feedstock, where the material is a ceramic powder, with each individual particle clad in the binder **404**.

Referring to FIG. **5**, in one embodiment, the cold spraying (step **304**) includes accelerating the solid feedstock **402** and a separate feedstock **502** of the binder **404** to at least a predetermined velocity or velocity range, for example, based upon the equation 1. In one embodiment, the cold spraying (step **304**) corresponding to FIG. **5** involves nozzles **408** designed with a combined A/A* ratio to suit spraying a particular material (either a metallic or low melting). In a further embodiment, the cold spraying (step **304**) uses different gases in different nozzles **408** and/or includes relative adjustment of other parameters. In one embodiment, multiple nozzles **408** are used to handle incompatibility associated with feedstock having a metallic phase and feedstock having a low melting phase, such as the separate feedstock **502** and the binder **404**. The solid feedstock **402** and the separate feedstock **502** impact the article **100** at the predetermined velocity or velocity range and the solid feedstock **402** bonds to the article **100** with the separate feedstock **502** and/or the binder **404** being entrained within the solid feedstock **402** and/or also bonding to the article **100**. The parameters are measured/monitored by sensors **410** positioned prior to the converging portion **406**.

In a further embodiment, the porosity of the thermal barrier coating **102** is controlled by varying an amount of the binder **404** applied in comparison to an amount of the solid feedstock **402** applied. Similarly, in one embodiment, the thermal conductivity of the thermal barrier coating **102** is adjusted. In one embodiment, the amount of the binder **404** is adjustably controlled by varying the amount of the binder **404** applied in comparison to the amount of the solid feedstock **402** while cold spraying (step **304**). In this embodiment, the porosity of the thermal barrier coating **102** varies based upon these amounts. In a similar embodiment, multiple layers are formed by cold spraying (step **304**) more than one application of the binder **404** (or another low-melt material) and the solid feedstock **402** with more than one relative amount of the binder **404** in comparison to the solid feedstock **402**.

For example, in one embodiment, the intermediate layer **202** (see FIG. **2**) positioned proximate to the substrate **101** or abutting the substrate **101** is less porous than the intermediate layer **202** (see FIG. **2**) positioned distal from the substrate **101** or at the surface of the thermal barrier coating **102** by the amount of the binder **404** applied to form the intermediate layer proximate to the substrate **101** being lower than the amount of the binder **404** applied to form the intermediate layer distal from the substrate **101**.

Referring again to FIG. **3**, in one embodiment, the process **300** continues after the cold spraying (step **304**) by removing (step **306**) the binder **404**. In one embodiment, excess amounts of the binder **404** are removed (step **306**) by heating the binder **404** and the solid feedstock **402** after the cold spraying (step **304**) to evaporate, burn, dissolve and/or sublime the excess amounts of the binder **404**. The removing (step **306**) of the excess amounts of the binder **404** forms the pores **104**.

In another embodiment, the process **300** continues after the cold spraying (step **304**) by further oxidizing metallic components in at least a portion of the thermal barrier coating **102**. The further oxidation increases the oxide content of the thermal barrier coating **102**. In one embodiment, further oxidation is performed by heating the thermal barrier coating **102** to a temperature sufficient to cause oxidation. In one embodiment, a chemical treatment is used to cause oxidation in the thermal barrier coating **102**. The oxide concentration in the thermal barrier coating **102** is increased by the oxidizing.

In one embodiment, the process **300** includes finishing (step **308**) the thermal barrier coating **102** and/or the article **100**, for example, by grinding, machining, shot peening, or otherwise processing. Additionally or alternatively, in one embodiment, the process **300** includes sintering the thermal barrier coating **102**, treating (for example, heat treating) the thermal barrier coating **102**, or other suitable process steps. In one embodiment, the treating converts the thermal barrier coating **102** from a composite coating into a ceramic coating. In a further embodiment, the ceramic coating includes titania, alumina, nickel oxide, cobalt oxide, iron oxide, nickel-cobalt oxide, nickel-iron oxide, cobalt-iron oxide, nickel-ytrria oxide, cobalt-ytrria oxide, iron-ytrria oxide, polyamide, nylon with glass fiber reinforcement, poly butylene terepthalate, polypropylene, polyethylene, polyphenylene sulfide, a blend of polyphenylene oxide and polystyrene, or a combination thereof.

While the invention has been described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A process of fabricating a thermal barrier coating, the process comprising:

cold spraying a substrate with a feedstock to form a thermal barrier coating on the substrate; and

concurrently oxidizing one or more of the substrate, the feedstock, and the thermal barrier coating;

wherein the cold spraying is in a region above the substrate having an oxygen concentration of at least 10%.

2. The process of claim **1**, wherein the oxygen concentration is provided by a process gas.

3. The process of claim **2**, wherein the process gas is air.

4. The process of claim **1**, wherein the oxygen concentration is provided by an inlet gas.

5. The process of claim **1**, wherein the oxygen concentration is above about 50%.

6. The process of claim **1**, wherein the oxygen concentration is above about 70%.

7. The process of claim **1**, wherein an oxide concentration is increased by an increase in the oxygen concentration.

8. The process of claim **1**, further comprising oxidizing at least a portion of the thermal barrier coating.

9. The process of claim **8**, wherein the oxidizing at least a portion of the thermal barrier coating includes baking in an oxygen containing atmosphere.

10. The process of claim **8**, wherein the oxidizing at least a portion of the thermal barrier coating includes chemical treatment.

11. The process of claim **1**, wherein the feedstock comprises mica.

12. The process of claim **11**, wherein a decomposition of the mica forms porosity in the thermal barrier coating.

13. The process of claim **1**, wherein the thermal barrier coating has graded porosity.

14. The process of claim **1**, wherein the feedstock further comprises a homogenous mixture of ceramic particles and a binder.

15. The process of claim **14**, wherein the ceramic particles comprise a material selected from the group consisting of 68.9 wt % Yb_2O_3, balance ZrO_2; high Y 55 wt %, balance ZrO_2; and combinations thereof.

16. The process of claim **14**, wherein the ceramic particles comprise a material selected from the group consisting of 30.5 wt % Yb_2O_3, balance ZrO_2; 24.8 wt % La_2O_3, balance ZrO_2; and combinations thereof.

17. The process of claim **1**, further comprising heating the feedstock prior to the cold spraying.

18. The process of claim **1**, further comprising heating the substrate prior to the cold spraying.

19. The process of claim **1**, further comprising heating the feedstock with a laser.

20. The process of claim **1**, further comprising heating the substrate with a laser.

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